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THE SO-CALLED CRETACEOUS DEPOSITS IN SOUTH-EASTERN MINNESOTA.

THE extent of Cretaceous formations in Minnesota has not yet been exactly determined. Small areas of the Cretaceous are known to be extant in several places and also large areas are believed to lie hidden under the drift in the western half of the state, adjacent to or continuous with the Cretaceous formations which occur in North and South Dakota and Iowa. In the region where large extent of Cretaceous is thought to exist in Minnesota, the glacial drift is very deep and the underlying formations are little, or not at all, accessible. In other regions where there is generally less drift, there is not much Cretaceous deposit. A few isolated areas only are reported to be Cretaceous-covered and these alone attest whether or not the Cretaceous deposits to the westward of Minnesota had once extended quite continuously eastward in the state to or beyond the central portions, as some geologists have thought. As far as has been ascertained, all known outcrops might well belong to local or even inland deposits. Again, whatever its extent, the Cretaceous now lies, when present, always immediately beneath the glacial drift and in this position it might presumably be found strongly eroded, and, therefore, we not only do not know the original extent of Cretaceous sedimentary deposits in Minnesota but also we cannot safely predict how much of that unknown quantity might now be extant.

The known extent of the Cretaceous in Minnesota is very small, while the sometimes estimated extent is very large. This statement may be well illustrated by reference to the final reports of the Minnesota Geological Survey, in which the maps of the several counties in volumes one and two, represent a few scattered spots of known Cretaceous, while the map of the state, in volume three, which is constructed from the same data shows one-half the area to be probably Cretaceous, beneath the drift. Further geological investigation must of course tend to lessen this enormous difference between the known and the possible Cretaceous. During the last two summers I have had opportunity to investigate the supposed Cretaceous in southeastern Minnesota with the surprising result that the reported areas and deposits, in some instances prove to be doubtful.

In this region, there have been mapped, as mentioned, probable Cretaceous areas, covering a small spot in Goodhue county, patches in Fillmore county, and a continuous area in Steele, Dodge, Mower, Freeborn, Faribault, Blue Earth, Brown and other counties. The reported known areas are that of Goodhue county, some clays in Mower county, near Austin, and gravels near Hamilton, small pockets of clay in Blue Earth and Scott counties and certain strata in Brown and Nicollet counties.

The last named is very probably Cretaceous. Near New Ulm, Brown county, have been found fossil leaves which are described by Leo Lesqueseaux[1] and referred by him to the Dakota group. I have visited the same locality and collected some of these fossils, which are abundant only in a thin discontinuous stratum of fine sandstone. The whole bed, consisting of coarse sand with some irregularly distributed clay is 30 feet or more thick and rests upon a rotted granitoid rock, which rises 10 feet above the level of the Cottonwood River. The fossil leaves were found a few feet only above the sandstone's base, in a layer which has a concretionary-like surface, and except for its width of several feet might be called a pebble, which other smaller fossil-bearing concretionary masses in the same zone certainly appear to have been. The leaves are found therefore in a broken stratum, which, however, was, with little doubt, contemporaneously deposited and broken, so that the contained flora is indicative of the formation's age. The materials of the sandstone are imperfectly asssorted and again almost arcose in character.

Other sand and clay exposures of the same age have been described from the neighborhood of New Ulm on the Minnesota River, but since they have afforded no further conclusive evidence, and since they too lie on the border or outside of what should be called southeastern Minnesota, I pass them by. Again, the supposed Cretaceous, which occurs farther down the Minnesota River valley at and below Mankato, might be passed perhaps justly with a denial that it is Cretaceous. Of course Cretaceous materials and fossils may be found in drift there and elsewhere in the state. But the beds of fine clay, containing some sand, which are on and in the Shakopee and Oneota dolomite formations, bear no fossils. They are like mere pockets of residuary clays from limestones and dolomites. They occur as white or variegated clays in the seams or in pockets or resting irregularly upon the iron-stained surfaces of the dolomites. Gravels of later age, possibly from early glacial drift, have been also described as Cretaceous, while others are possibly early Pleistocene, possibly Cretaceous. There is little or no conclusive evidence of the age of these small deposits. They need therefore no detailed description here, but a full account of them can be found in Final Report, Vol. I, p. 432; Vol. II, p. 127, Minnesota Geological Survey.

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[1] Minn. Geol. Surv., Vol. III.

The reported Cretaceous at Austin, Mower county, is more important, because upon its character has depended the coloring of several counties on the geological map. Austin lies about 60 miles southeast of Mankato, 85 miles therefore in the same direction from New Ulm. The map coloring from Mankato to Austin depended upon the occurrence of supposed Cretaceous at Austin. Here occurs a variegated clay ranging in color from pea-green to bright red and yellow, resting upon a limestone or dolomite of Devonian age. It has not however been found in place, but is always, as far as known, involved in the glacial débris. Whatever the origin of this clay, it is now glacial drift, a Pleistocene deposit, and therefore not properly to be mapped as Cretaceous.

Regarding the question whether or not these clays were derived from Cretaceous formations, it must be said that the evidence indicates strongly that they were not. For example, a large pit opened by the Austin Brick and Tile Works showed about ten feet of clay of all colors jammed together, bearing bowlders of granite, especially in the upper part, and large blocks of Devonian limestone, especially in the lower part. There is no mistaking the blocks of limestone, for they pass gradually into that which underlies in heavy strata throughout this region. The limestone blocks are blue or buff like the Devonian strata in color, though, locally, they are found in every degree of decomposition, so that in one place a complete series from fresh rock to iron concretion and red clay can be gathered. At Varco, below Austin, in quarries of the Austin Cement Works, a preglacial channel about ten feet deep in the Devonian limestone is well shown, and in it the rock surface is black stained and decomposed. Upon this surface is a somewhat disturbed, variegated clay, not in strata but coating the inclined surface. Reconstructed, the preglacial condition around Austin seems to have been simply that the Devonian limestone, blue in original color, passed upwards into buff of the same formation. This, twenty feet or more thick, was penetrated by clay-filled cracks at the top, or covered by a coating of black iron-manganese oxide, etc., from one to two inches thick ; the former condition passing to a red clay with black concretions and decomposing brownish limestone blocks ; the other phase, that of the black unbroken rock surface, as at Varco, passing simply into homogeneous residuary clay. The pea-green clay is calcareous and it was not residuary but formed strata or laminæ between the limestones. Such a clay is seen in the Devonian at Le Roy, in the southeastern part of the county,[1] and again it should not be forgotten that the Devonian at Austin extends upwards nearly to the horizon of the Rockford shales, so well developed southward in Iowa.

The identification of the clays at Austin as Cretaceous was based upon a few specimens of fossil leaves found in digging a well (*vide op. cit.* p. 354). At first the subjacent limestone was also called Cretaceous by N. H. Winchell, but this mistake was soon corrected through the identification of fossils by H. S. Williams. The occurrence of a true Cretaceous fossil in this Pleistocene deposit does not prove the origin of the clays, because also pre-Cambrian rocks and Devonian fossils are scattered quite abundantly in it. The Austin clays are not Cretaceous and it is very doubtful that they ever could have been such.

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[1] See also Geol. Surv. Minn., Vol. I, p. 357, l. 7.

Another supposed Cretaceous deposit has been described, also by N. H. Winchell in the northeastern part of Mower county. There is, in this district, a "white pebbly conglomerate which passes into a ferruginous grit." In the adjacent part of Fillmore county, the same occurs, and was identified as Cretaceous. Near Spring Valley, a few miles farther south, a blue clay is said to represent the Cretaceous. No actual outcrops were known of strata *in situ*, and one might not now refer any of these to the Cretaceous, especially since the "Austin rock" is now known to belong to a different formation. Indeed, they were so referred only with doubt by Professor Winchell. Of course, Cretaceous as well as Devonian, Ordovician, Cambrian and older rock débris might be found commingled in the Pleistocene drift.

In Goodhue county, about sixty miles northward from Austin and ninety east of New Ulm, there is another deposit consisting of interstratified clay and sand, which is described by N. H. Winchell as Cretaceous.[1] Fossil leaves have been found in the sandstone and are identified by Leo Lesquereaux as Cretaceous fossils.[2] I have verified the occurrence of the leaf imprints, though of course their identification is not questioned. The fossils belong to the same age as the strata and the latter are therefore of Cretaceous origin since the former are.

Before describing this patch of sand and clay, it may be recalled that the deposit lies beyond the limits of Wisconsin and Iowan drift in the region of loess and Kansan or pre-Kansan drift. It is in an undulating prairie bordering on the deep valleys which lead to the Mississippi valley about twelve miles

[1] Op. cit., Vol. II, p. 43.

[2] They are described in Final Rep., Vol. III, Minn. Geol. Surv.

distant toward the northeast. The Cretaceous lies on one of the higher hills of the prairie. It is covered by the loess five to ten feet thick, which also covers the Kansan eskers, the Saint Peter sandstone of the butte-like hills and, at lower levels, the Shakopee dolomite hills, and then, on the steep sides of the valleys, the Oneota dolomite and Jordan sandstone. The glacial till or gravel is spread beneath the loess, over the same Cretaceous, Ordovician and Cambrian formations. Under this drift, the dolomite formations are commonly protected by a dark-colored residuary clay, containing chert and iron concretions. Two or three miles to the westward from the Cretaceous patch, the Saint Peter sandstone is conformably overlaid by the Galena (Trenton), and upon that may once have rested the Maquoketa (Hudson) strata. Now at the particular locality where the Cretaceous patch occurs, there is neither Galena nor Maquoketa extant, but the Cretaceous rests upon the Saint Peter sandstone or possibly in part upon the Shakopee dolomite. Further, it is evident, as shown by N. H. Winchell (*op. cit.*) and others, that all the geologic formations, from the Galena down to and below the Jordan sandstone, were once, in this region at least, uniform, coextensive, sedimentary deposits, and that all the valleys are due to later erosion. This valley cutting was accomplished before the glacial deposits were spread on them. The erosion of the loess and glacial till and gravels now going on is very slight as compared to that which produced the valleys over which those deposits have since been spread.

The Cretaceous strata lie where erosion had already obtained. The Galena series, at least, must have been eroded away before Cretaceous deposit could be laid upon Saint Peter sandstone. Again, the valleys on either side of this Cretaceous, as we now see it, must be younger than such a sedimentary formation if the same is *in situ*, else the formation should lie in the valley and not on a hill. This Cretaceous patch, like the hills of Saint Peter sandstone and of other older formations in the same locality, must be the outlier or eroded remnant of a once more extensive sedimentary deposit; unless, like the bowlders of granite, the gravels and the till, it was transported by the glacier *en masse* from the northwest.

The Cretaceous in Goodhue county is known to cover about one-half square mile from 0 to 40 feet deep. It lies in sections 3 and 10, town of Goodhue, three miles northward from Goodhue village, and one and one-half miles east of Clay Bank station. It consists of a succession of sand and clay strata which are now quite irregular, although when deposited they could not have been so. The top of the mass always shows disturbance from a glacier which has moved over it, although comparatively lightly, from a northwesterly direction. In the many pits which form a long series of exposures, no stratum appeared undisturbed, but rather every one has been shifted on the other. "The thickness of the parts varies in short distances, some of the beds tapering to points and wholly disappearing."[1]

It should be emphasized, that the irregularities of the twenty or more successively alternating sand and clay strata, are not due to sedimentation as believed heretofore, but to later dislocation which was evidently glacial. In the most regular sequence observed, which is seen in a pit on the west side of the highway, every stratum has been shifted upon the other. In other exposures they show even more irregularities, and it is quite impracticable to describe all the peculiarities of this kind. But all of them are modifications of a once regular series of alternating clay and sand strata which, as is shown by their continuity in some cases, were probably very uniform and continuous when deposited as sediment. In one case a fairly regular succession now forms a syncline. The strata dip on the one side at an angle of fifteen degrees for forty feet at least. The other side is steeper and shorter. One coarse sandstone stratum in particular runs uniformly two feet thick down one side and up the other. It could not have been so deposited. A clay stratum on the contrary is bunched into a lenticular mass in the syncline. It would not have been so deposited. Rather frequently a sand stratum is interrupted or widely isolated in thick lenticular masses, then included in the clay. An exceptional case of dislocation is seen in one corner of the easternmost exposure. Here a mass of sand, eight to ten feet wide and exposed ten feet deep, interrupts the strata. Its median portion, vertically, shows obscure horizontal stratification. On the right and left, clay only, joins irregularly on the sand in large confused masses, which project in an irregular sheet two feet thick, over the same. Probably the clay extends under it. The adjacent sand strata are cut off or squeezed out abruptly by the clay, which surrounds the large sand mass. In composition this sand horse is coarser than any of the strata, but near by the same kind of coarse sand was found scattered loosely over the top, like drift. It is not ordinary glacial sand however.

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[1] WINCHELL, op. cit., p. 44, l. 6.

Lamination is generally obscure. The clay is without lime and is decidedly tough and fine in texture. The sandstones are either nearly white and friable, or have been converted to a veritable crystallized iron ore in parts of the same stratum. It is in the dark red hard parts of the sand strata that the fossil leaf imprints occur. These parts of the strata have resisted distortion, being only here and there brecciated, so that character of stratification, like the fossils, may be clearly discerned. The rock alterations must have preceded the mechanical disturbance of the strata. Small pieces of mica further characterize the sand and coarser clays of the strata.

Excepting in the case described above, the strata are not jammed together but appear rather to have slid one on another. Even the top in contact with the glacial drift is not mixed with pebbles or bowlders, although it has been distorted to the depth of one to three feet by the glacier. The till, two feet thick or merely a thin covering of gravel, with here and there a large bowlder perched up into the loess instead of buried in the Cretaceous clay, overlies the whole mass.

What lies beneath the Cretaceous here is unfortunately not known, except in the southern part of the field, where an excavation for the railway passes through the Saint Peter sandstone. The top of exposed Saint Peter rises as high as that of the Cretaceous. It is crusted over in one place with a black coating of iron. Upon it is found a few inches of unassorted fine sand like that of the Saint Peter sandstone, and numerous small bright pebbles, while in other places the loess rests upon it instead. On either side of the Saint Peter sandstone are Cretaceous strata which are now weathered, however, and their relation to the Saint Peter is no longer clearly defined in the exposure. But they seem to have conformed to the surface of the latter, without intervening deposit. The generally undulating arrangement of the strata in all the pits argues also that they conform to an irregular or undulating surface beneath them.

If the strata had been deposited just where they now lie, they would have been unconformable to the underlying structure, and horizontal instead of inclined. The strata have been disturbed if not transported *en masse*. Whether they have been moved a few feet or a few hundred miles remains to be shown. Likewise, one must define the mass as either in its originally deposited character, Cretaceous, or as now glacial drift. An elaborate discussion on how far rock must be moved out of location before it is to be called drift, would end in this case, however, only in the recognition of the fact that possibly some unexposed stratum may be still *in situ* as Cretaceous.

I endeavored to find some proof that this patch is an outlier of a once widespreading formation of this region. The striking presence of mica sand argues a general formation rather than a local one. In Cretaceous time, the only known source of mica must have been either granitoid rocks far to the northeast or to the northwest, or possibly the Saint Lawrence formation and Cambrian sandstones, the exposures of which could have been only far distant, while Cretaceous sediments were depositing three hundred feet above them in this region of nearly horizontal formations. Moreover I did not find that the Saint Peter sandstone detritus forms any part of this Cretaceous rock. Yet, the Saint Peter stands adjacent and protrudes to the height of the other deposit. The materials are evidently from distant sources. In the vicinity of this particular hill are other hills or buttes which must be equally high, because they cut off the view of the more distant horizon. On these hills are farmhouses, with the never-failing wells two hundred feet deep. Excavations for cellars have also been made, but although the value of the "Clay Bank" must inevitably have been impressed upon every mind in the neighborhood, still no one is known to have observed similar clays or equivalent deposits on other hills. It is very probable that they do not exist.

In view of this contradictory evidence, other hypotheses were sought which might harmonize them. It may be suggested that either the deposit was that of a meandering river, or that the mass has been borne hither by the capricious glacier. To the former hypothesis there is the seeming objection, that the alternating strata of uniform composition and sharply defined stratification, do not suggest a river flood deposit, but it may explain the presence of mica in the sand. To the other hypothesis, however, no objection arises which cannot be circumvented.

The mass of clay and sand is large, and cannot be compared to any mass of granite or of limestone which are found among erratics; but the Galena (Trenton) shales which are tougher than limestones are known to have been transported *en masse* by the Wisconsin glaciers. Bodies of this kind are known within the city limits of St. Paul, Minnesota. One is at St. Anthony Park station, and although it is much distorted, is yet mainly unmixed with foreign materials and is highly fossiliferous, It is exposed in four places within half a square mile. At Dale and Martin streets, a similar body covering an acre and possibly a much larger area, lies in the drift high above the horizon of the shales *in situ* as exposed in the region. At Stickney, Curtice and Concord streets, a somewhat smaller mass has been cut through by the Chicago and Great Western railway, and this mass preserves the stratification quite completely although the strata form a syncline and an anticline and overlap the till. These masses, however, have necessarily been transported more than one half or one or two miles from where they were dislodged.

The Cretaceous near Goodhue is very much tougher than the shaly clays of the Galena (Trenton) at St. Paul. The clay strata when wet would scarcely fracture under any conditions and the sand strata between them, being largely not compacted, could allow them more free movement and keep the mass from breaking apart, as long as the strata remained approximately horizontal or compressed. Moreover there is little instead of much gravel and till associated with it into which it might have been jammed by the glacier. The condition of the glacier at the time when this mass could have been dropped where it now lies, is indicated by a fine example of an esker which lies about one mile west of south, looking like one of the sandstone buttes or a dolomite swell. The esker presents an abrupt slope on its northwestern front, and extends indefinitely to the southeastward. At the foot of the esker is an exposure of Saint Peter sandstone. The brow of the hill has been excavated for a sand pit, and the strata of gravel may be seen in it dipping gently on all sides into the hill. Thin strata of nearly pure sand, unlike anything but Saint Peter sandstone, are conspicuous. The depth of the gravel is about forty feet, but the loess covering obscures the form of the hill and conceals the most of the esker deposit. A similar esker lies nearly two miles farther in the same direction, standing west of the village of Goodhue. The eskers and the Cretaceous lie in line, and notably they are perched on the brow of sandstone hills, fronting northwesterly. Again, the height of these eskers contrasts with the thinness of the till, which is only one or two feet thick, as seen in cuttings in the region. The glacier which strewed débris thinly, and which scarcely drove the residuary clays from the rock surfaces beneath it, must still have been a gigantic ice mass to have built such eskers on the farther side of a broad valley. A clay mass such as the Cretaceous here, would have been comparatively slight when once loaded upon the ice.

It is not my intention to urge this hypothesis of glacial transportation, but it is worthy of remark that the successive loose sand and tough clay strata would have been the best adapted of any to be easily slid upon the glacier, to be transported without disruption, and to be laid down without dissolution. The peculiar rolling up of sand strata into lenticular masses between clay strata might not be easily produced by any single continued thrust of an overlying glacier, but might easily be the result of successive reverse sliding movements.

Very little, if any, attention has been paid to this Clay Bank by geologists since N. H. Winchell briefly described it, but it is not without scientific interest in its present significance, whether it is Cretaceous or Pleistocene. It has also a high commercial value. Professor Winchell believed that this clay and sand deposit might extend over several square miles and he has represented about sixteen sections on the map of Goodhue county (*op. cit.*). He has described a number of observed and reported Cretaceous exposures as occurring from two to fifteen miles distant, but none of these afford the desired evidence. Clays like that at Clay Bank might of course be expected to occur in other places in the drift and only the occurrence of strata unquestionably *in situ* can prove the same to have been deposited as Cretaceous, not as Pleistocene, in this region. There are also two other deposits which may be mistaken in this region for Cretaceous. One, the ferruginous conglomerates of the oldest drift, a sort of residuum of the oldest till, occurs here and there. No ferruginous conglomerate nor any gravels were observed in the strata of the Clay Bank, and indeed none are known to be from Cretaceous strata. A more deceptive deposit in this particular region is the variegated clays of the Shakopee formation. Such an exposure is seen one mile north of Clay Bank station in a railway cutting, where three or four feet of clay strata cover the side of a dolomite swell. When weathered, this clay remains long intact, while the dolomite strata above and beneath it are reduced. It might then be mistaken for a Cretaceous clay.

There are no Cretaceous deposits known in southeastern Minnesota which are unquestionably *in situ*, although Cretaceous clays, with fish teeth and bones or fossil leaves in sandstone, are not infrequently discovered in any of the "northwestern drift" in Minnesota. Their occurrence does not prove the proximity of Cretaceous strata. Other supposed Cretaceous rocks are very evidently not such. With the exception perhaps of the half square mile in Goodhue county, no areas should be indicated on the map in southeastern Minnesota either as known or probable Cretaceous. At, or a little beyond, the western border of the region herein considered, the first Cretaceous begins, *i. e.*, near New Ulm.

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UNIVERSITY OF MINNESOTA,
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